Use of High Altitude Platform Systems to Augment Ground Based APNT Systems

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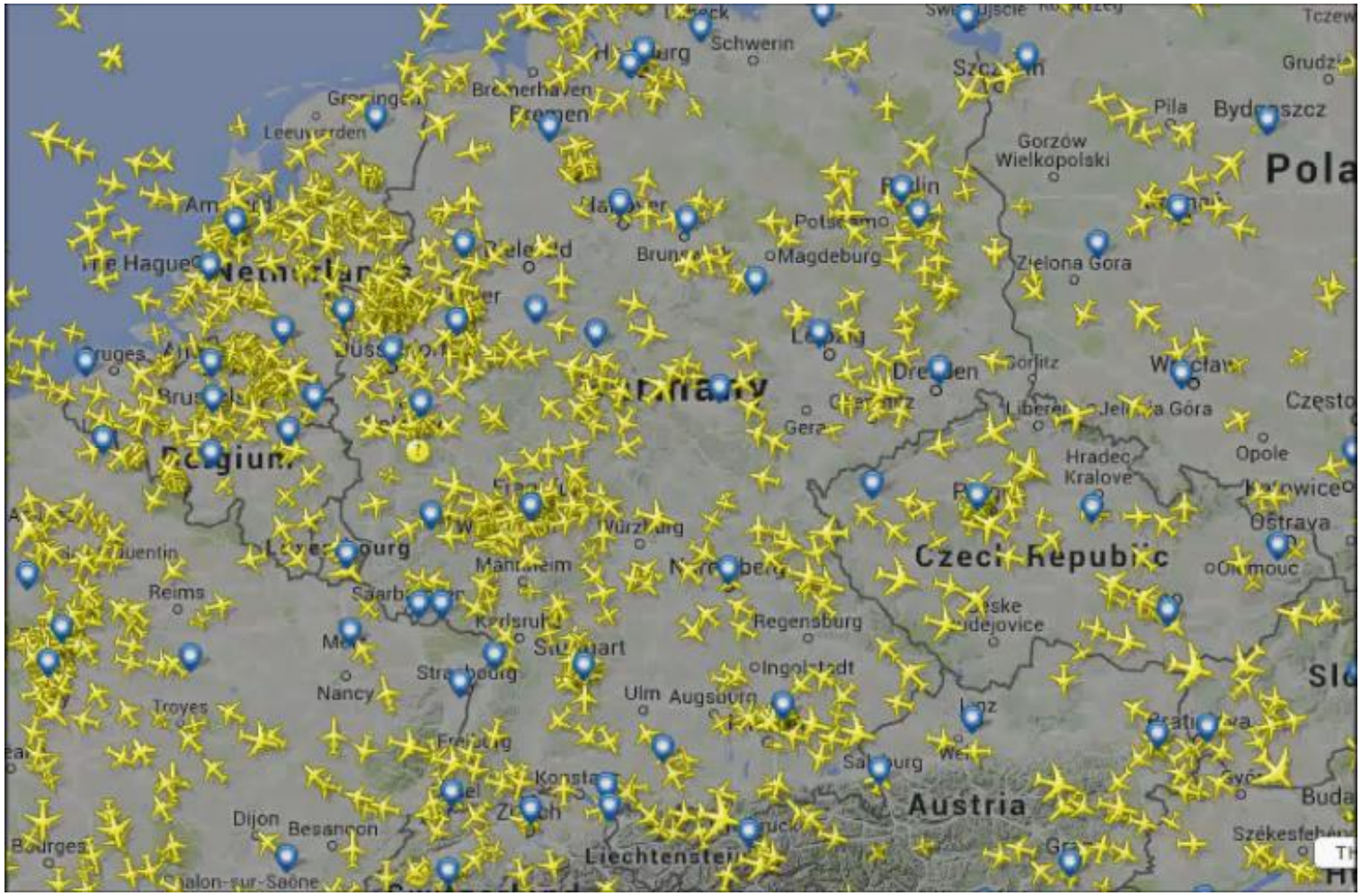
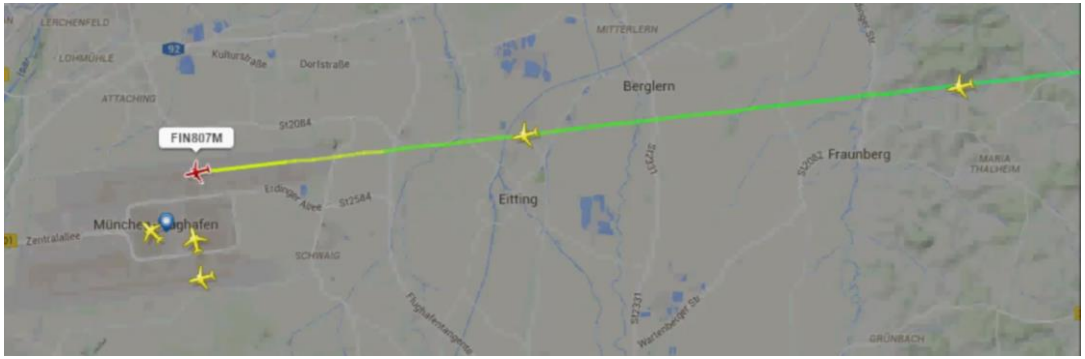
Motivation



Source: flightradar24.com

Motivation



Source: *flightradar24.com*

SESAR and NextGen:

"GNSS as primary navigation system"

Higher Air Traffic Density thanks to GNSS reliability:

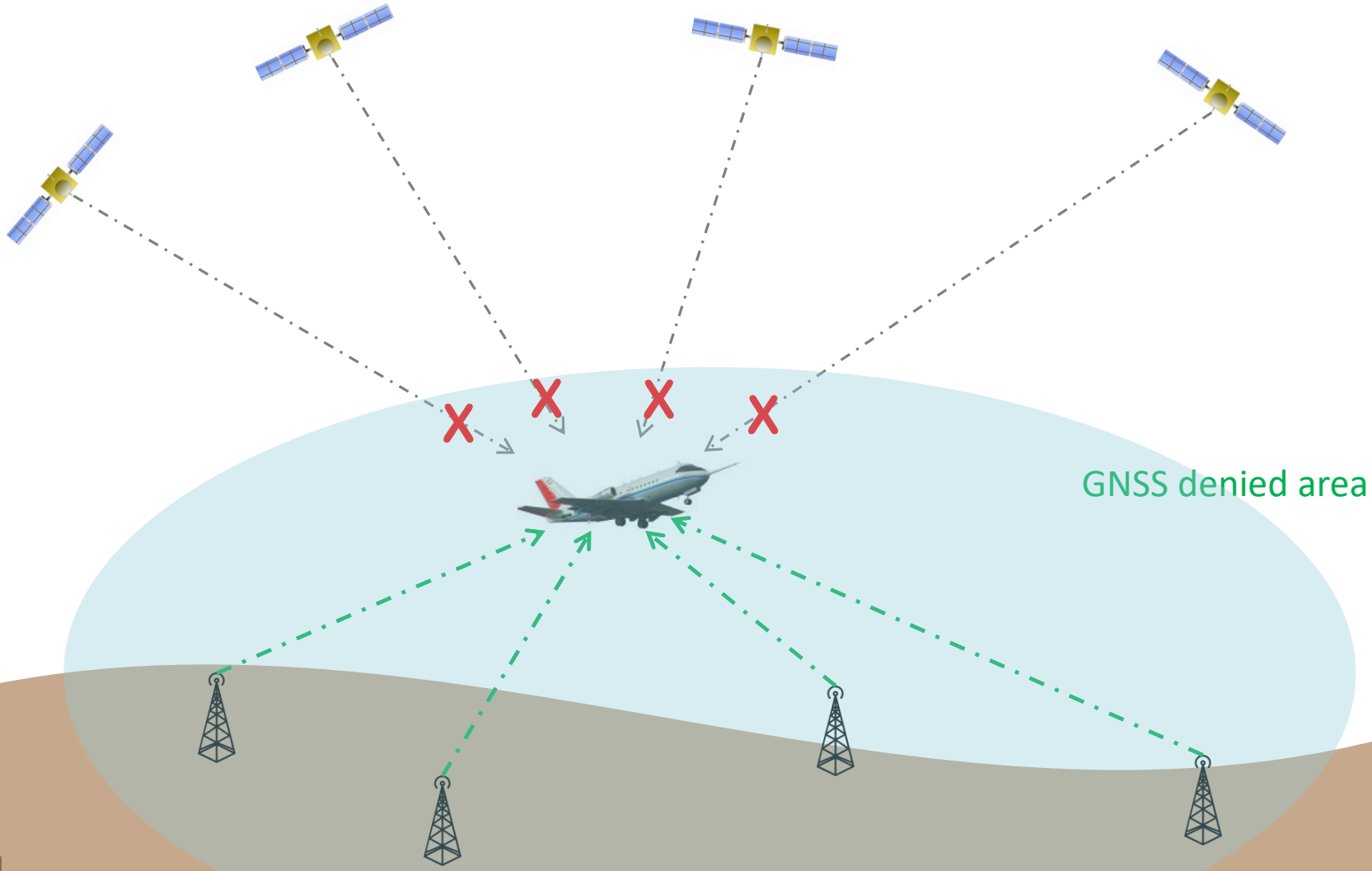
- SBAS
- GBAS
- ARAIM

Concern about relying only on GNSS (Radio Frequency Interference)

Need for a back-up system

- Transition to lower performance navigation
- Bring aircraft safe to a landing system

Alternative Position, Navigation and Timing (APNT)



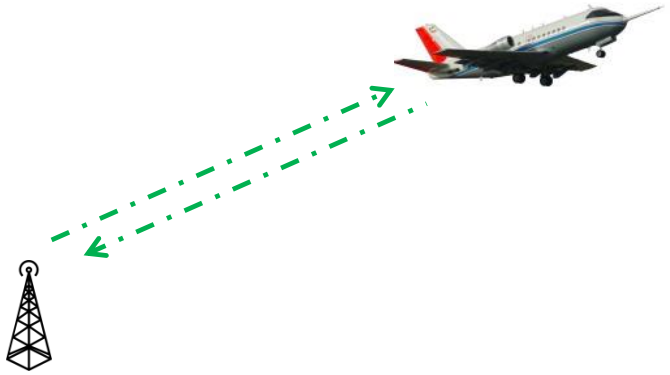
APNT Ground Signals

Signals under consideration:

- Distance Measurement Equipment (DME), eDME
- L-band Digital Aeronautical Communications System (LDACS)
- Universal Access Transceiver (UAT)
- Mode S transponder/1090 Mhz (ADS-B)

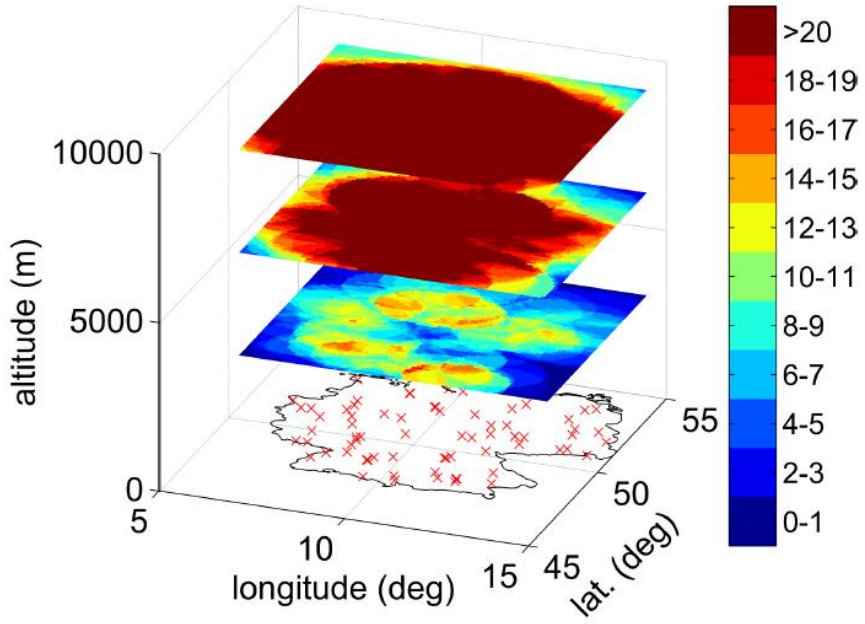
Ranging

- One way ranging
- Two way ranging
- Hybrid one/two way ranging

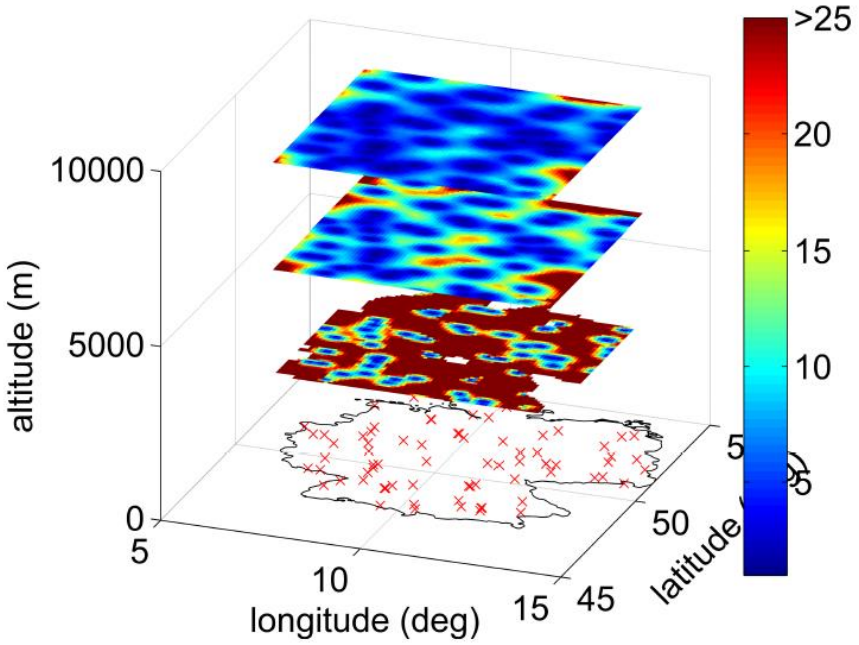


Ground Visibility limitations

Number of Visible Stations

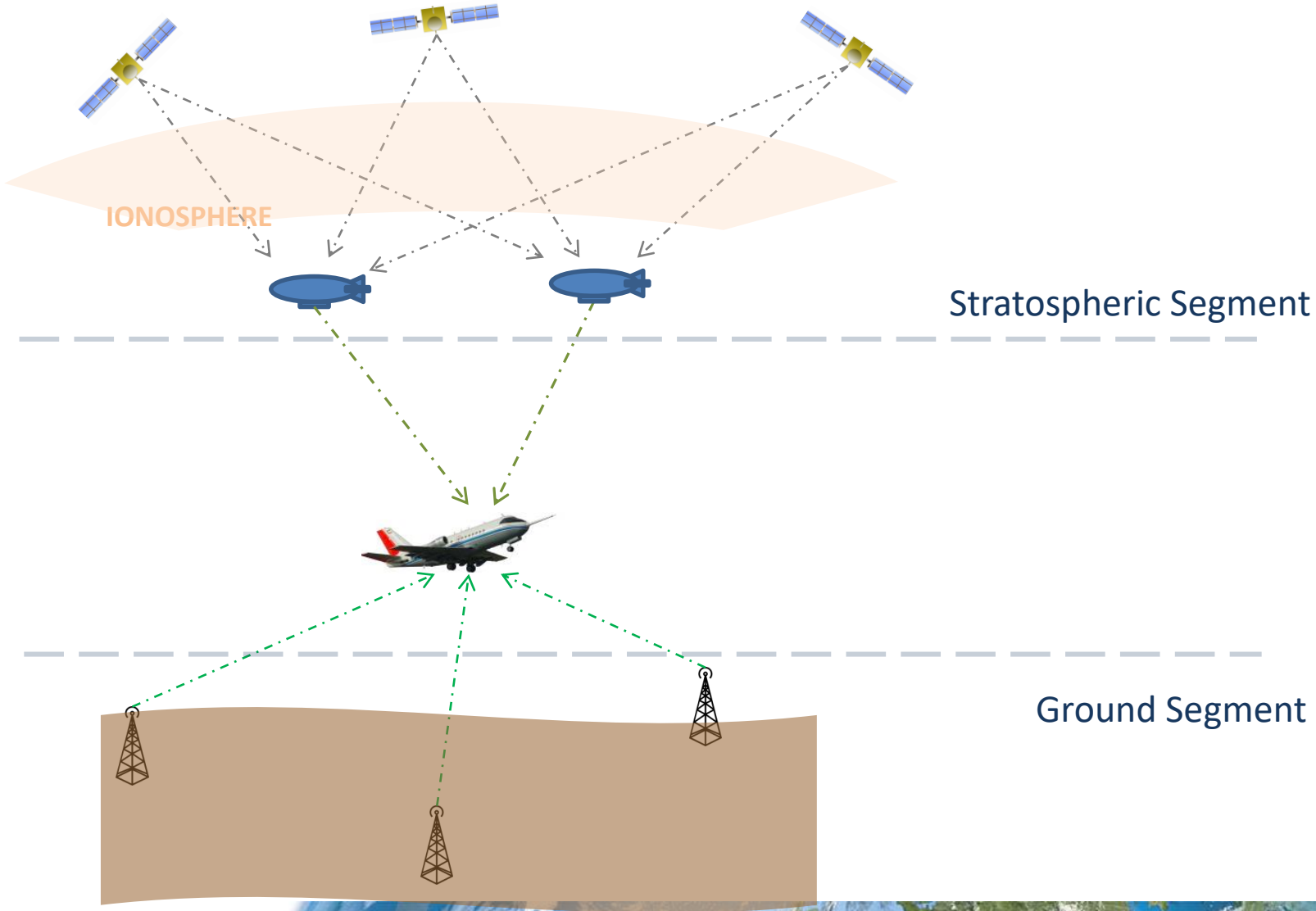


Geometric Dilution Of Precision



Problems of convergence of positioning algorithms

Ground-Stratospheric APNT System



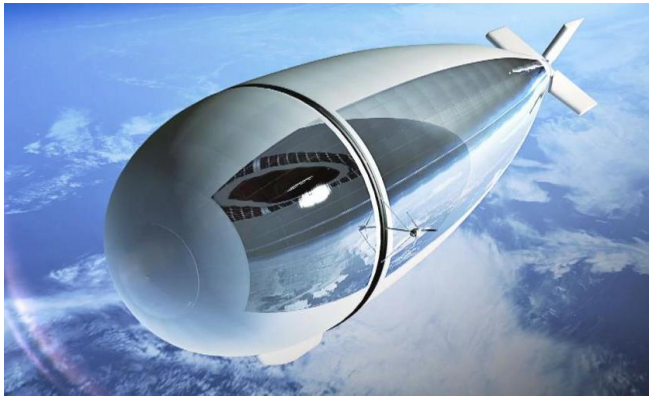
High Altitude Platform Systems (HAPS)

Characteristics:

- Operates in the stratosphere: altitude 17-22 km
- Line of sight visibility with big area of the Earth
- Solar powered for long operations
- Ranges free of ionospheric errors
- Quasi-stationary position
- Lower cost in deployment compared to a satellite
- Easier to replace & maintenance

Applications:

- Wireless Communication
- Earth Observation
- Surveillance
- Navigation



Related work (Navigation)

GNSS Pseudolite (stratolite) & GNSS Augmentation

- G. Boiero *et al.*, “Increasing the Spatial Limits of LADGPS Using Stratospheric Platform,” *J. Navigation*, Royal Inst. Navigation, May 2001.

- I. Ozimek, T. Javornik, and F. Dovis, “Navigation-Related Services over Stratospheric Platform,” Electrotechnical Review, Ljubljana, Slovenija, vol. 71(3), pp. 96–102, 2004.

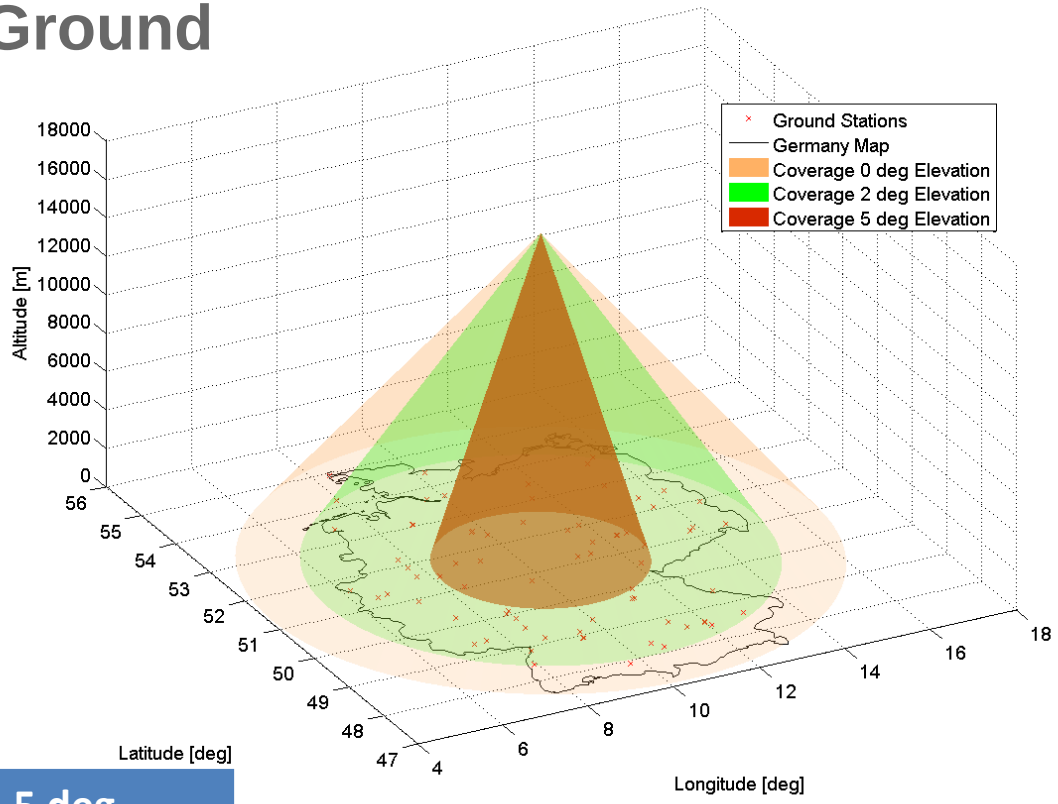
- F. Dovis, L. Lo Presti, and P. Mulassano, “Support infrastructures based on high altitude platforms for navigation satellite systems,” IEEE Wireless Communications, October 2005.

Surveillance

- M. Leonardi, S. Spinelli, and G. Galati, “ADS-B/MLAT surveillance system from High Altitude Platform Systems,” in Proceedings of ESAV’11, 2011, pp. 153–158.

Geometric Coverage: Ground

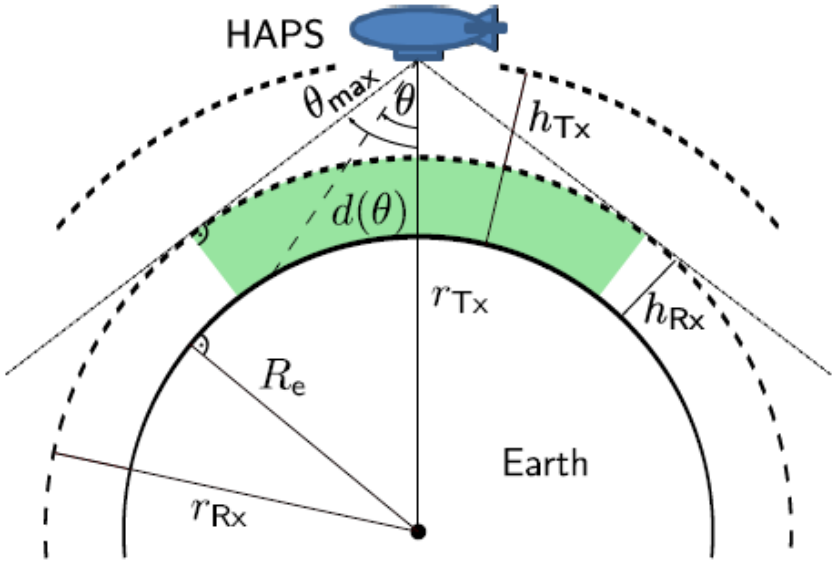
Example of Germany:
HAPS at 17 km



	0 deg	2 deg	5 deg
α [deg]	**85.82**	85.37	83.48
S [km^2]	679449.63	269603.17	89089.62
D [km]	**930.31**	585.94	336.81
d [km]	465.98	293.83	169.48

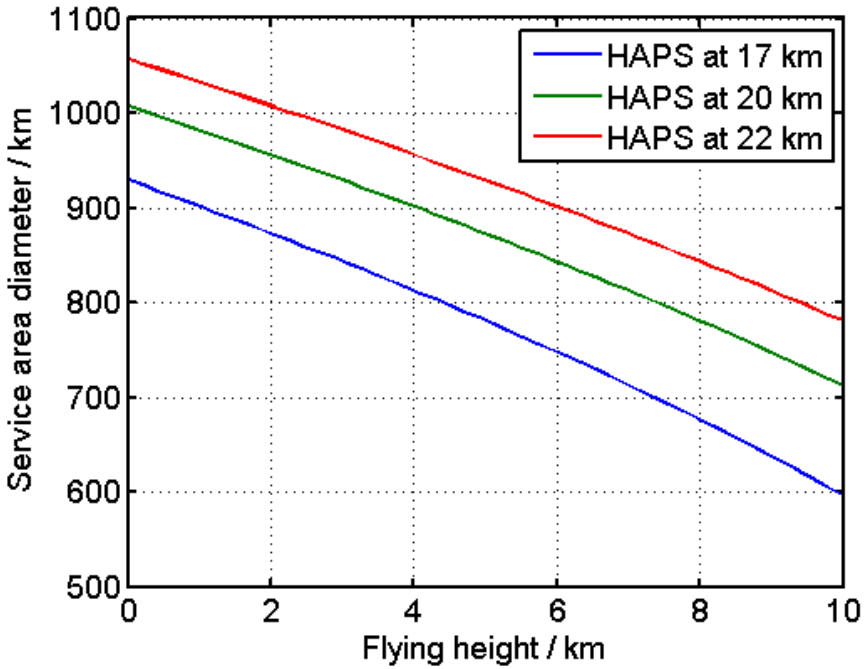
We can cover the whole Germany with one HAPS

Geometric Coverage: Airborne



$$\theta_{\max} = \sin^{-1}(r_{\mathrm{Rx}}/r_{\mathrm{Tx}})$$

$$d_{\max} = \sqrt{r_{\mathrm{Tx}}^2 - R_e^2} = \sqrt{2R_e h_{\mathrm{Tx}} + h_{\mathrm{Tx}}^2}$$



Diameter of Service Area:

$$D = 2R_e \cos^{-1}\frac{r_{\mathrm{Rx}}}{r_{\mathrm{Tx}}}$$

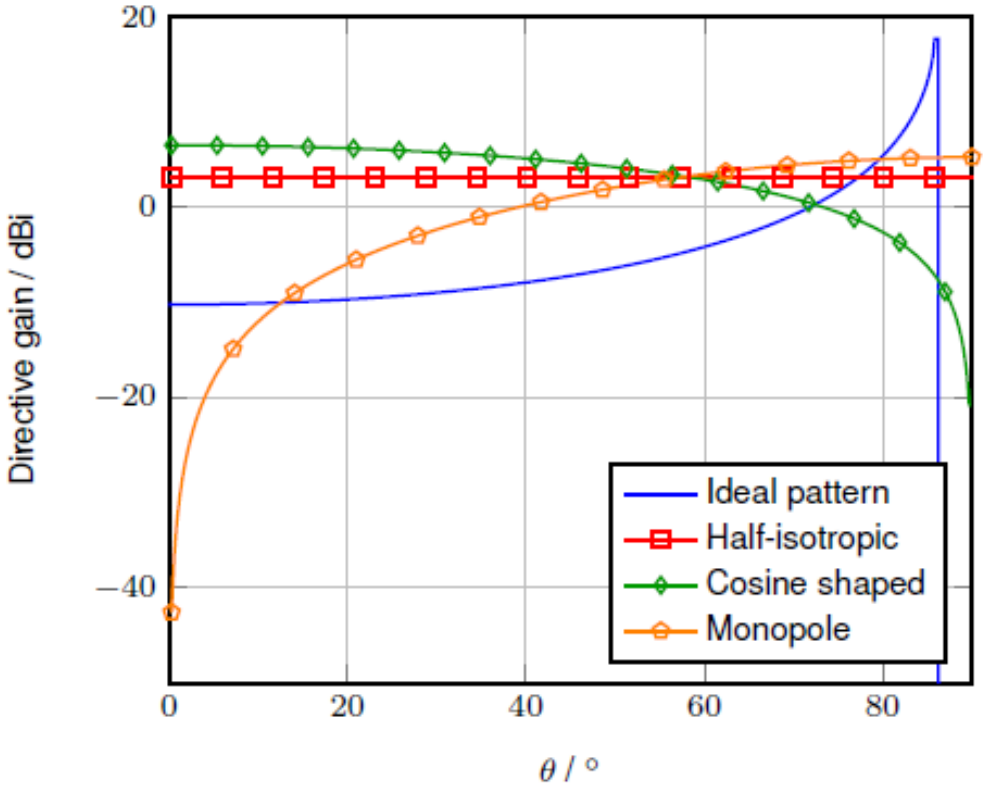
Link Budget and Ideal Antenna Pattern

$$P_{Rx} = \frac{P_{Tx} g_{Tx} g_{Rx}}{L_{Rx} L_{Tx} L_{FS} L_{M}}$$

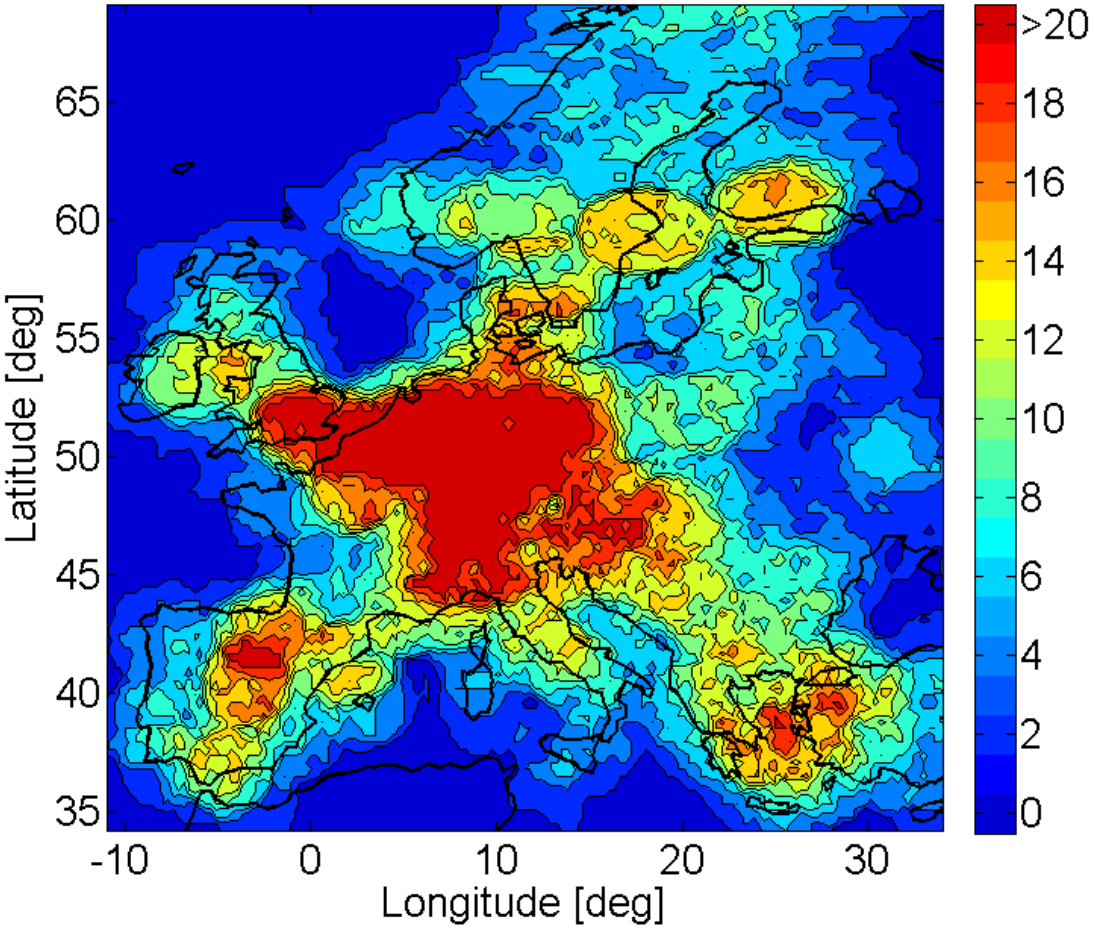
$$L_{FS}(\theta) = \left(\frac{4\pi}{\lambda} d(\theta)\right)^2$$

Example:

- Max Angle: 86.2 deg
- Rx Sensitivity: -100 dBm
- Freq: 1164 Mhz



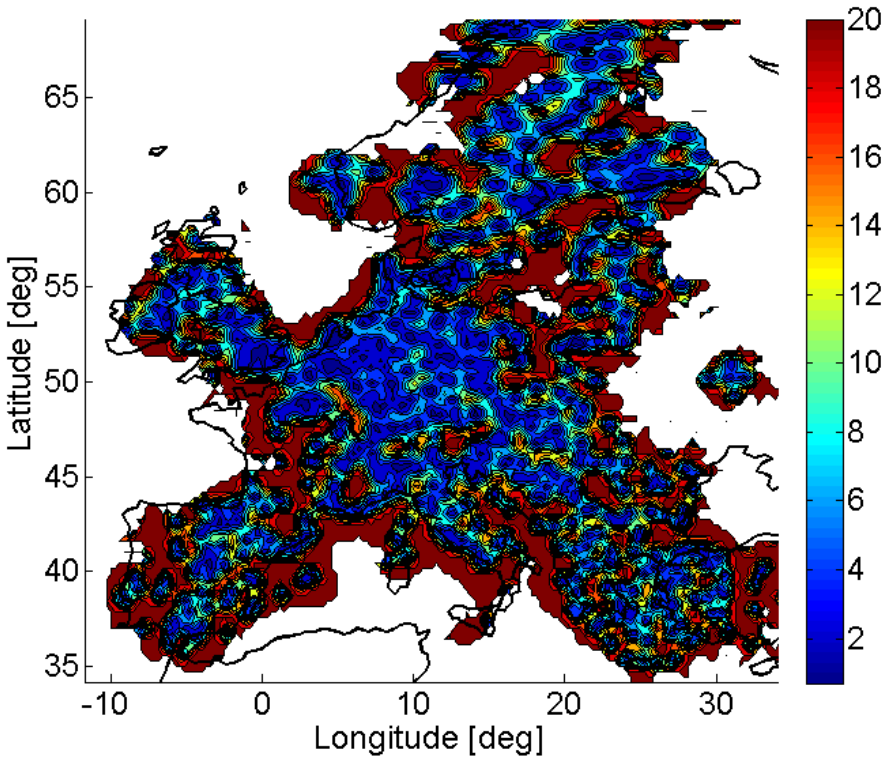
Number of visible DME stations in Europe at 20.000 ft



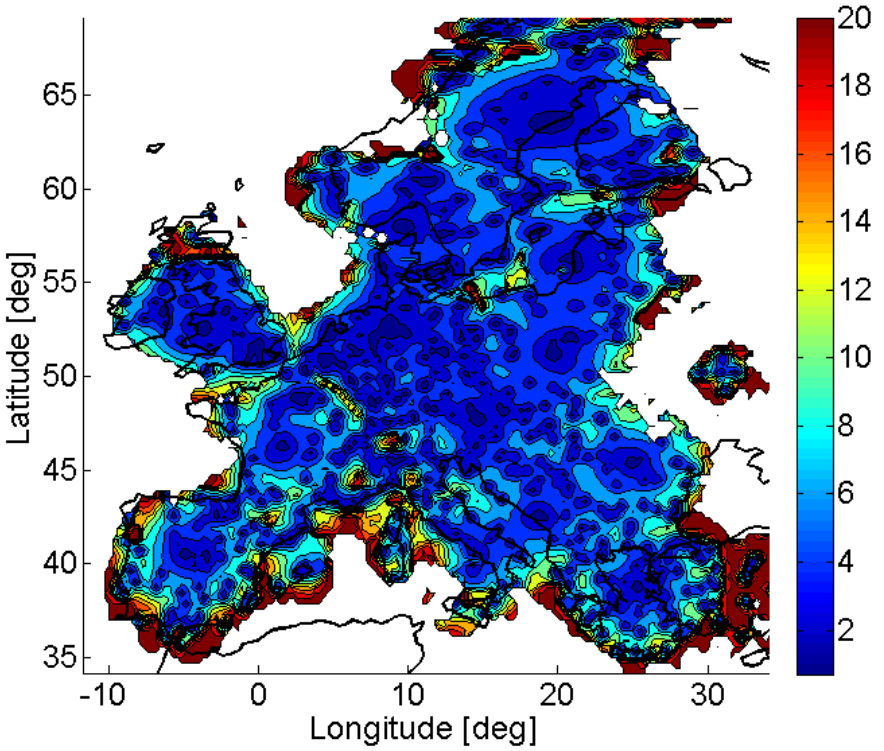
Ground Stations:

- DME locations
- Radio horizon coverage with 1 degree elevation
- Maximum range distance of 120 nm

HDOP enhancement in Europe at 20.000 ft.

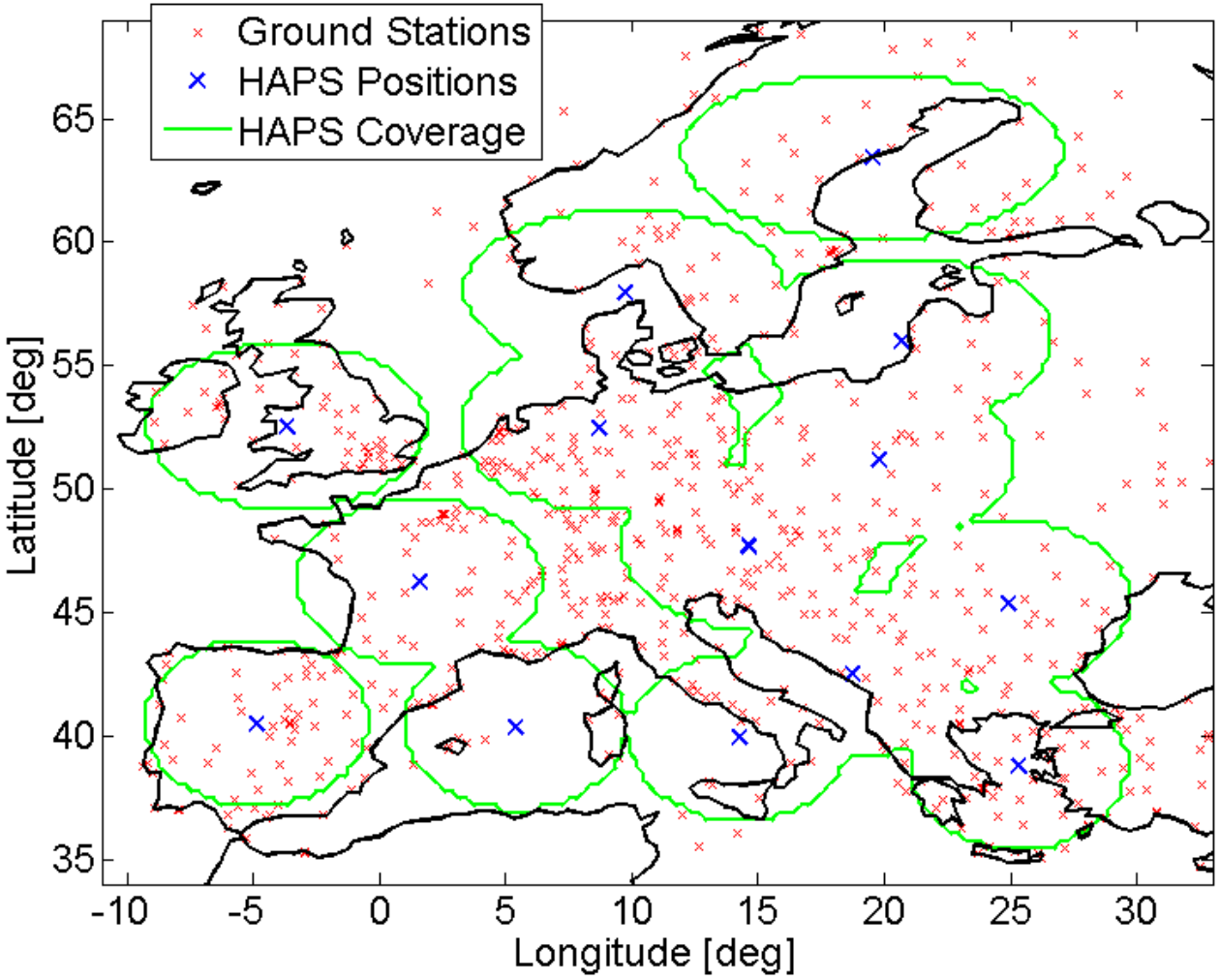


Only DME Stations

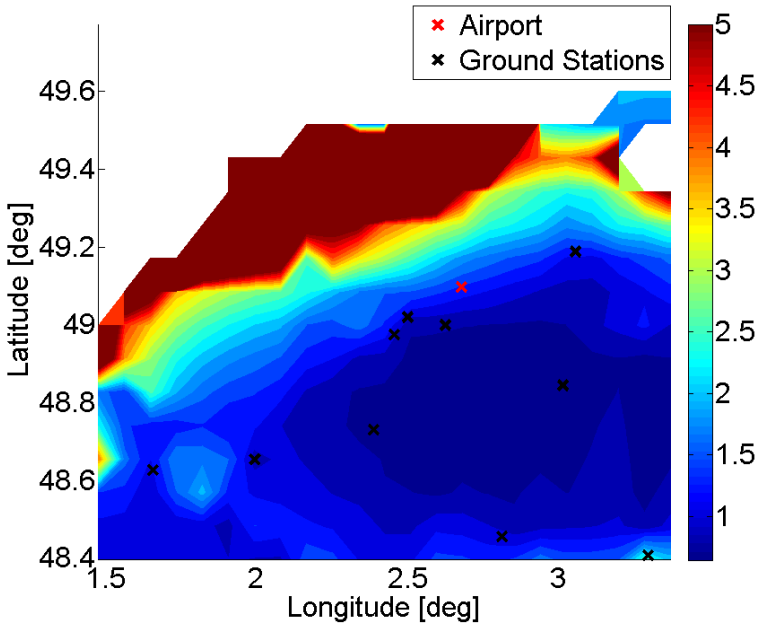


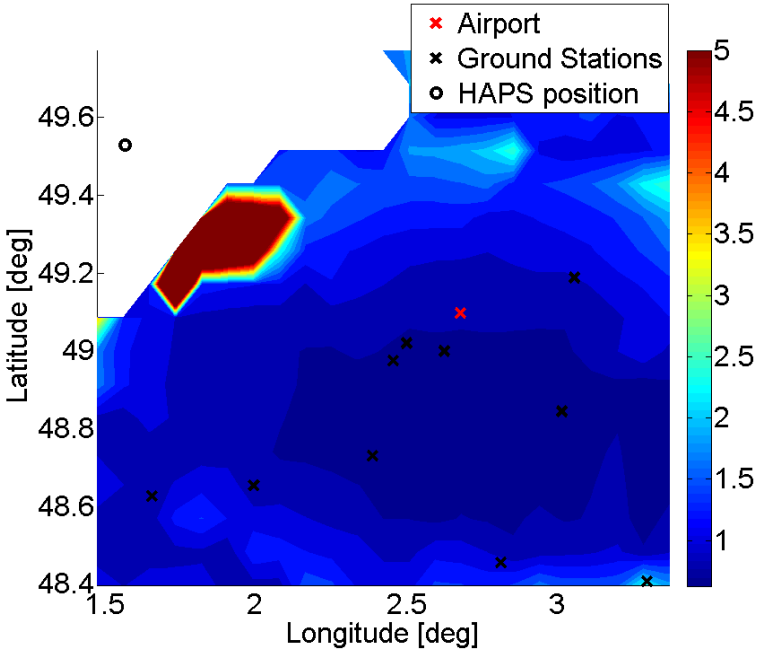
DME Stations and 17 HAPS at 20km

HAPS Coverage Europe Example



HDOP Enhancement at Airport Vicinity (5.000 ft)

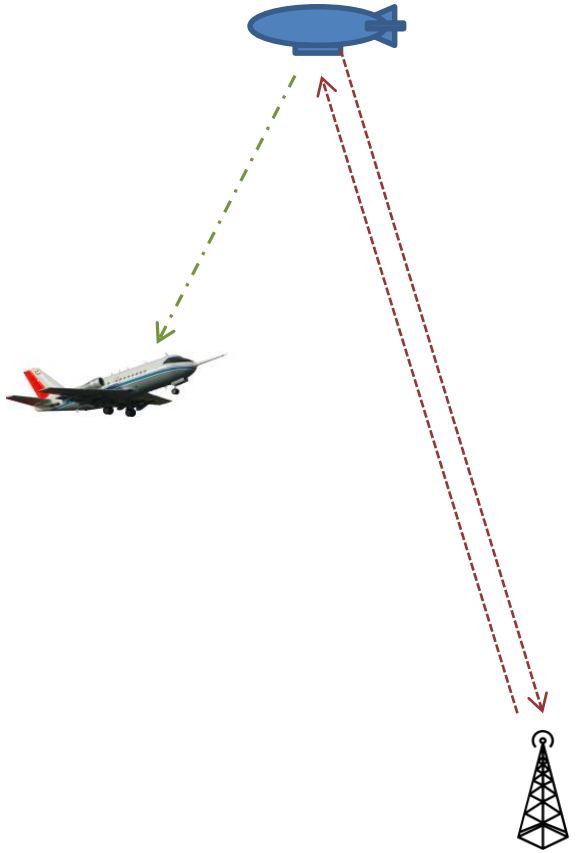




HAPS can open new approaches directions or help in limiting terrains

Further Applications of HAPS for APNT

- HAPS as additional pseudolites:
- HAPS for APNT Time Synchronization
- HAPS can monitor the signals from the ground stations (Integrity Monitoring).



Conclusions

- HAPS could be used as a range source for APNT:
  - Enhance geometric diversity
  - Improve HDOP
  - Increase navigation service area
- One HAPS can potentially provide coverage over 900 km
- Antenna design is not straight forward and would need a dedicated design
- HAPS could be a solution for the ground stations time synchronization
- HAPS for APNT augmentation and Integrity Monitoring would be a new APNT service

Thanks you